

## **Massachusetts Stretch Energy Code Recommendation For Revising Boiler Efficiency Requirements**

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### **Summary**

Stretch Code Table 507.2.1(5) establishes the prescriptive requirements for boilers. Many requirements specified in the Stretch Code table exceed the product efficiencies available in the commercial marketplace. The issue is that requirements are set too high to be non-proprietary. Revised boiler requirements are essential to allow Stretch Code implementation and the basis of these revised requirements should be existing industry standards. New boiler efficiency requirements are proposed in this document.

### **Introduction**

Boilers are classified into three market segments or sizes based on gross output capacity (in British Thermal Units per hour, Btu/h). In addition, two fuel types, gas and oil, and two boiler outputs, hot water or steam, need to be assessed for each size category. The gross output capacities are listed below:

- **Small (often referred & specified as Residential)** < 300,000 Btu/h
- **Mid Range Commercial** 300,000 -2,500,000 Btu/h
- **Large Commercial** >2,500,000 Btu/h

Boiler performance standards specify specific performance for each size category and each fuel type so the resulting requirements specification will have 24 categories covering all size categories, fuel types and hot water & steam outputs.

Boiler efficiencies can be rated in different performance metrics. Annual Fuel Utilization Efficiency (AFUE) is the U.S. standard for rating all boilers < 300,000 Btu/h. AFUE is a steady state annual measure that calculates the heat transferred to the space divided by the fuel energy consumed. Thermal efficiency (Et), a steady-state peak measure unlike AFUE, is usually used for mid-range commercial size boilers and sometimes for large commercial boilers. Combustion efficiency is the most common metric for large boilers. Thermal efficiency measures the ratio heat energy output to fuel input exclusive of jacket & heat loss through the boiler shell. Combustion efficiency (Ec) only measures the ability of a boiler to burn fuel, subtracting off flue losses. Theoretically combustion efficiency would equal fuel efficiency but in reality losses usually occur and can be a couple percent in magnitude for significantly more. Unfortunately, there is not a mathematical correlation between any of these efficiencies. This can make comparison of different codes and standards difficult when different measures, i.e. thermal efficiency and combustion efficiency, are used for the same categories.

## **Issues**

Table 507.2.1(5): BOILER, EFFICIENCY REQUIREMENTS from Stretch Code presented obstacles to the specification of product in many categories. Three separate issues were identified including:

- **Requirements Exceed Commercially Available Product** – The minimum requirements were set at either 90% Et or 89% Et for every category specified regardless of whether the boiler was generating hot water or steam and whether the fuel utilized was natural gas or oil. Gas-fueled hot water boilers can easily meet and exceed these efficiency ratings but steam generating boilers have much lower efficiencies. The steam boiler ratings are set significantly above existing industry standards & codes including IECC (International Energy Conservation Code) & ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) with the exception of the Core Performance Guide 1.01 TABLE 2.9.4 – BOILERS from the New Buildings Institute. The Core Performance Guide 1.01 is the source of the Stretch Code ratings.
- **Size Category, <300,000 Btu/h** – This size category was specified in thermal efficiency when the national standard for this category is AFUE. Thermal efficiency ratings are rarely available for boilers of this size.
- **Missing Category, Gas Hot Water  $\geq 2.5$  MBtu/h** – Gas hot water boilers are widely used and due to condensing boiler technology highly efficient but the category of  $\geq 2.5$  MBtu/h was missing from this chart for no apparent reason.

As previously noted the Core Performance Guide is the basis of the boiler minimum requirement. The New Buildings Institute (NBI) which publishes this guide has acknowledged the issues but does not have a proposed replacement specification for Stretch Code.

## **Review of Existing Industry Standards & Codes**

An analysis of existing boiler standards was performed versus the stretch code and is summarized in **Table 1 - Boiler Minimum Efficiency Requirement**. The following were reviewed for comparison purposes along with Stretch Code:

- **MA-CHPS 2009, the Massachusetts Collaborative for High Performance Schools**
- **IECC 2009**
- **ASHRAE 90.1-2007**
- **ASHRAE 189.1** - Standard for the Design of High-Performance, Green Buildings

**Table 1 - Boiler Minimum Efficiency Requirement**

Type	Fuel	Size Category	Stretch Code	Core Performance Guide 1.01	MA-CHPS 2009	IECC 2009	ASHRAE 90.1-2007	ASHRAE 189.1
STEAM	Gas	< 300,000 Btu/hr	89% Et	89% Et	89% Et	75% AFUE	75% AFUE	75% AFUE
		300,000 - 2,500,000 Btu/hr	89% Et	89% Et	89% Et	75% Et & 80% Ec	75% Et	77% Et / 79% Et <sup>a</sup>
		> 2,500,000 Btu/hr	89% Et	89% Et	89% Et	80% Ec	80% Ec	77% Et / 79% Et <sup>a</sup>
	Oil	< 300,000 Btu/hr	90% Et	90% Et	90% Et	80% AFUE	80% AFUE	80% AFUE <sup>b</sup>
		300,000 - 2,500,000 Btu/hr	89% Et	89% Et	89% Et	78% Et & 83% Ec	78% Et	81% Et
		> 2,500,000 Btu/hr	89% Et	89% Et	89% Et	83% Ec	83% Ec	81% Et
HOT WATER	Gas	< 300,000 Btu/hr	90% Et	90% Et	90% Et	80% AFUE	80% AFUE	89% AFUE <sup>c</sup>
		300,000 - 2,500,000 Btu/hr	89% Et	89% Et	89% Et	75% Et & 80% Ec	75% Et	89% Et <sup>c</sup>
		> 2,500,000 Btu/hr	Not Listed	Not Listed	89% Et	80% Ec	80% Ec	91% Ec <sup>c</sup>
	Oil	< 300,000 Btu/hr	90% Et	90% Et	90% Et	80% AFUE	80% AFUE	89% AFUE <sup>c</sup>
		300,000 - 2,500,000 Btu/hr	89% Et	89% Et	89% Et	78% Et & 83% Ec	78% Et	89% Et <sup>c</sup>
		> 2,500,000 Btu/hr	89% Et	89% Et	89% Et	83% Ec	83% Ec	91% Ec <sup>c</sup>

<sup>a</sup> Use first listed efficiency for gas-fired natural draft boiler, use second listed efficiency for all other boiler types.

<sup>b</sup> ASHRAE 189.1 standard mistakenly listed Et rating in this category, efficiency should be in AFUE & ASHRAE has committed to fixing in next update.

<sup>c</sup> Systems shall be designed with lower operating return hot water temperatures (<130°) and use hot water reset to take advantage of the higher efficiencies of condensing boilers.

Comparison of the existing standards above resulted in these observations and conclusions:

1. Stretch Code - All efficiencies are rated in thermal efficiency and listed as either 89% or 90%(with the exception of the missing category).
2. Core Performance Guide 1.01 – Boiler requirements are identical to Stretch Code since this guide is the basis for Stretch Code.
3. MA CHPS 2009 – The efficiencies are also identical to Stretch Code with one addition, a rating was added for the missing large commercial size, gas hot water boiler.
4. IECC 2009 - This code lists lower efficiencies for hot water systems. IECC 2009 is the basis of the current base building code and does not support the efficiency goals of Stretch Code. Steam boiler ratings are significantly lower than Stretch Code. Both thermal efficiency and combustion efficiency requirements are provided for mid-range boilers and combustion efficiency is used for large boilers.
5. ASHRAE 90.1-2007 – This standard is an alternative for meeting existing Massachusetts building code and also lists lower efficiencies for hot water systems, missing the opportunity to improve efficiency. All performance ratings are similar to IECC 2009, although the thermal efficiency metric is used for mid-range boilers.
6. ASHRAE 189.1 –The steam boiler ratings are significantly lower than Stretch Code. The ratings for ASHRAE 189.1 are identical to Stretch Code for mid-range commercial gas hot water boilers (89% Et). For

small and large boilers, the ratings cannot be compared to Stretch Code because they are in different performance metrics. For example, the largest boilers are specified in most cases in ASHRAE 189.1 by combustion efficiency, but thermal efficiency in Stretch Code.

The next revision of the Core Performance Guide is under review. It was not used in this analysis. As an unpublished guideline, it is not viewed as a substitute for the current version of stretch code. Over time, the next revision will be incorporated into IECC and as it becomes non-proprietary it will be appropriate for inclusion in future releases of Massachusetts building code.

## **Recommendation**

ASHRAE 189.1 was designed to improve energy efficiency over ASHRAE 90.1-2007 by 20-30%. The primary goal of Stretch Code was a 20% improvement over current Massachusetts building code. This supports the use of ASHRAE 189.1 as a basis for determining higher performance boiler specifications for Stretch Code.

But changes were needed to some of the ASHRAE 189.1 categories for several reasons (see Table 2 for listing of changes). In some cases, the standard minimum efficiency was set too high to specify three manufacturers (non-proprietary). The standard was lowered by one percentage point at a time until three manufacturers could be specified. The American Heating and Refrigeration Institute (AHRI) website provides performance certifications for HVAC products including boilers. Commercial and residential size boilers can be identified at this site <http://ahrinet.org/>

Since the standards sometimes used different efficiency measures in a category, additions were made in some categories to the ASHRAE 189.1 minimum efficiency requirements. One example is for gas-fueled steam boilers, mid-range commercial and large commercial. IECC 2009 listed both thermal and combustion efficiency ratings in the midrange size categories but ASHRAE 189.1 listed only thermal efficiency. Since combustion efficiency and thermal efficiency can theoretically be the same or range by multiple percentage points, additional ratings were added into these categories to insure that the minimum efficiency would not drop below the base building code.

The recommended efficiencies are listed in the Proposed Column of the **Table 2- ASHRAE 189.1 Based Boiler Analysis Table**. Specific changes to ASHRAE minimum requirements are explained for each category in the last column, Changes to ASHRAE189.1 in **Table 2** (on the next page).

**Table 2 - ASHRAE 189.1 Based Boiler Analysis Table**

Type	Fuel	Size Category	ASHRAE 189.1	Proposed	Changes to ASHRAE 189.1
STEAM	Gas	< 300,000 Btu/hr	75% AFUE	75% AFUE	
		300,000 - 2,500,000 Btu/hr	77% Et / 79% Et <sup>a</sup>	77% Et / 79% Et <sup>a</sup> & 80% Ec	Added "80% Ec" to ensure minimum as strict as current code
		> 2,500,000 Btu/hr	77% Et / 79% Et <sup>a</sup>	77% Et / 79% Et <sup>a</sup> & 80% Ec	Added "80% Ec" to ensure minimum as strict as current code
	Oil	< 300,000 Btu/hr	80% AFUE <sup>b</sup>	80% AFUE <sup>b</sup>	
		300,000 - 2,500,000 Btu/hr	81% Et	81% Et & 83% Ec	Added "83% Ec" to ensure minimum as strict as base code
		> 2,500,000 Btu/hr	81% Et	81% Et & 83% Ec	Added "83% Ec" to ensure minimum as strict as base code
HOT WATER	Gas	< 300,000 Btu/hr	89% AFUE <sup>c</sup>	89% AFUE <sup>c</sup>	
		300,000 - 2,500,000 Btu/hr	89% Et <sup>c</sup>	89% Et <sup>c</sup>	
		> 2,500,000 Btu/hr	91% Ec <sup>c</sup>	91% Ec <sup>c</sup>	
	Oil	< 300,000 Btu/hr	89% AFUE <sup>c</sup>	89% AFUE <sup>c</sup>	
		300,000 - 2,500,000 Btu/hr	89% Et <sup>c</sup>	87% Et <sup>c</sup>	Lowered by 2% Et to achieve non-proprietary with certified products
		> 2,500,000 Btu/hr	91% Ec <sup>c</sup>	87% Ec <sup>c</sup>	Lowered by 2% Et to achieve non-proprietary with certified products

<sup>a</sup> Use first listed efficiency for gas-fired natural draft boiler, use second listed efficiency for all other boiler types.

<sup>b</sup> ASHRAE 189.1 standard mistakenly listed Et rating in this category, efficiency should be in AFUE & ASHRAE has committed to fixing in next update.

<sup>c</sup> Systems shall be designed with lower operating return hot water temperatures (<130°) and use hot water reset to take advantage of the higher efficiencies of condensing boilers.

The results from the AHRI website are listed in the Appendix with specific manufacturers listed in **Table A - Boiler Manufacturers for Revised Stretch Code Requirements**. The analysis was completed in August 2010, reflecting certified product availability at that time.

## Conclusion

The revised boiler requirements resolve the issues with Stretch Code Table 507.2.1(5). The following **Table 3 – Boiler Efficiency Requirements** lists the proposed requirements which are being submitted to the state of Massachusetts for review. These requirements can be achieved with available boilers and are non-proprietary. The adoption of these revised boiler requirements for Stretch Code is recommended to the state.

**Table 3 – Boiler Efficiency Requirements**

Type	Fuel	Size Category	Proposed
STEAM	Gas	< 300,000 Btu/hr	75% AFUE
		300,000 - 2,500,000 Btu/hr	77% Et / 79% Et <sup>a</sup> & 80% Ec
		> 2,500,000 Btu/hr	77% Et / 79% Et <sup>a</sup> & 80% Ec
	Oil	< 300,000 Btu/hr	80% AFUE <sup>b</sup>
		300,000 - 2,500,000 Btu/hr	81% Et & 83% Ec
		> 2,500,000 Btu/hr	81% Et & 83% Ec
HOT WATER	Gas	< 300,000 Btu/hr	89% AFUE <sup>c</sup>
		300,000 - 2,500,000 Btu/hr	89% Et <sup>c</sup>
		> 2,500,000 Btu/hr	91% Ec <sup>c</sup>
	Oil	< 300,000 Btu/hr	89% AFUE <sup>c</sup>
		300,000 - 2,500,000 Btu/hr	87% Et <sup>c</sup>
		> 2,500,000 Btu/hr	87% Ec <sup>c</sup>

<sup>a</sup> Use first listed efficiency for gas-fired natural draft boiler, use second listed efficiency for all other boiler

<sup>b</sup> ASHRAE 189.1 standard mistakenly listed Et rating in this category, efficiency should be in AFUE & ASHRAE has committed to fixing in next update.

<sup>c</sup> Systems shall be designed with lower operating return hot water temperatures (<130°) and use hot water reset to take advantage of the higher efficiencies of condensing boilers.

**Appendix:**

**Table A - Boiler Manufacturers for Revised Stretch Code Requirements**

Type	Fuel	Size Category	Minimum Efficiency	Manufacturers
Steam	Gas	< 300,000 Btu/h	75% AFUE	Pennco Boilers Raypak Inc. Williamson-Thermofold
		300,000 Btu/h - 2.5mBtu/h	77% Et/79% Et <sup>a</sup> & 80% Ec	Burnham Commercial P B Heat LLC Weil-McClain
		> 2,500,000 Btu/h	77% Et/79% Et <sup>a</sup> & 80% Ec	Burnham Commercial Smith Cast Iron Weil-McClain
	Oil	< 300,000 Btu/h	80% AFUE	Crown Boiler Co Slant/Fin Corporation Smith Cast Iron Boilers
		300,000 Btu/h - 2.5mBtu/h	81% Et and 83% Ec	P B Heat LLC Smith Cast Iron Weil-McClain
		> 2,500,000 Btu/h	81% Et and 83% Ec	Burnham Commercial Smith Cast Iron Weil-McClain
Hot Water	Gas	< 300,000 Btu/h	89% AFUE <sup>b</sup>	Carrier Corporation RBI Water Heater/Div of Mestek NY Thermal Inc.
		300,000 Btu/h - 2.5mBtu/h	89% Et <sup>b</sup>	Aerco International, Inc. Heat Transfer Products Inc. Raypak Inc.
		> 2,500,000 Btu/h	91% Ec <sup>b</sup>	Bosch Thermotechnology Corp. Camus Hydronics Ltd. Viessmann Manufacturing Inc.
	Oil	< 300,000 Btu/h	89% AFUE <sup>b</sup>	Bosch Thermotechnology Corp. Columbia Boiler Co./Pottstown P B Heat, LLC
		300,000 Btu/h - 2.5mBtu/h	87% Et <sup>b</sup>	Bosch Thermotechnology Corp. Burnham Commercial Viessmann Manufacturing
		> 2,500,000 Btu/h	87% Ec <sup>b</sup>	Bosch Thermotechnology Corp. Burnham Commercial Viessmann Manufacturing

<sup>a</sup> Lower Et rating applies to gas-fired, natural draft boilers, higher Et to all other types.

<sup>b</sup> Systems shall be designed with lower operating return hot water temperatures (<130°F) and use hot water reset to take advantage of the higher efficiencies of condensing boilers.